Geohazard mapping and evaluation for a natural gas pipeline project

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POWER

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DIGITAL GEOLOGIC MAPPING

How do you safely fast-track a complex geohazard mapping project with these following challenges:

- 1850 km in length varying in elevation from sea level to over 3,000 m.
- Eight teams of geologists from four different countries.
- The imminent arrival of inclement weather.
- Challenging terrain from boggy agricultural land to mountainous peaks.
- Multiple geohazards – active faults, landslides, karst, liquefiable soil
- Limited public roadways.

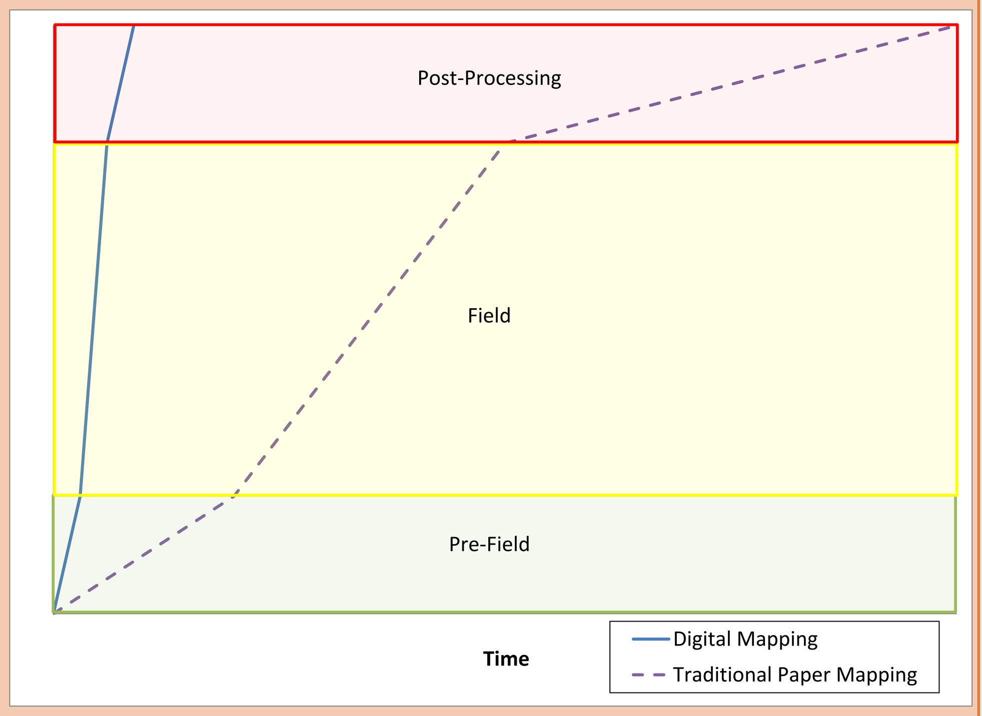
With the use of digital geologic mapping, which is the process of collecting geological data using an integrated hardware/software system!

This poster demonstrates how the use of digital geologic mapping and tablet PCs helped fast-track this demanding project allowing completion in under 40 days.

Advantages of digital geologic mapping and tablet PCs include the following:

- Integrated cameras allow geotagging of photographs automatically linking them to a map location.
- GPS simplifies the task of locating oneself on a base map.
- GPS allows the geologist to walk around an outcrop, landslide, or other significant feature and automatically track its boundaries within the software.
- Seamless integration with Bechtel's GIS software.
- Rapid preparation of field data (compared to printing hard copy maps with mylar overlays).
- Data is collected electronically thereby reducing / eliminating data transfer errors from the field to the office, reducing rework.
- Ability to easily "carry" a variety of maps (topographic, geologic, orthophotos, etc.).

TIME: GIS resources are significantly reduced. Preparing, printing, and folding eight sets of maps (including overlays for each geohazard) at 1:10,000 scale would require three months. One set of maps (base map with five overlays for geohazards) for the entire alignment at 1:10,000 scale would require printing over 3,700 A4 sheets.



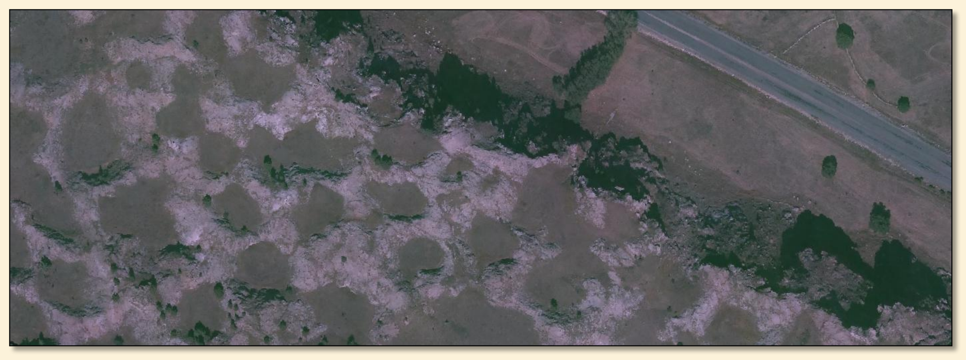
EFFORT: A printed map is a static map and does not allow for any modification. Digital maps allow the user to zoom in on a complex area, as well as turn on and off layers that may be hiding important information. Digital maps eliminate common issues with adverse field conditions such as rain or low light In addition, common issues such as tearing paper maps or damaging them through erasing are eliminated. Digital maps permit frequent updates to the geologists as new data becomes available in the office. This eliminates printing and shipping of paper maps. Digital maps with annotations eliminate errors in transcribing poorly written field notes.

COST: Use of solely digital maps eliminates the cost with printing field maps. Reduced time in preparation of maps results in lower labor costs. Efficiency gains in the field results in shortened schedule and again lower labor costs.

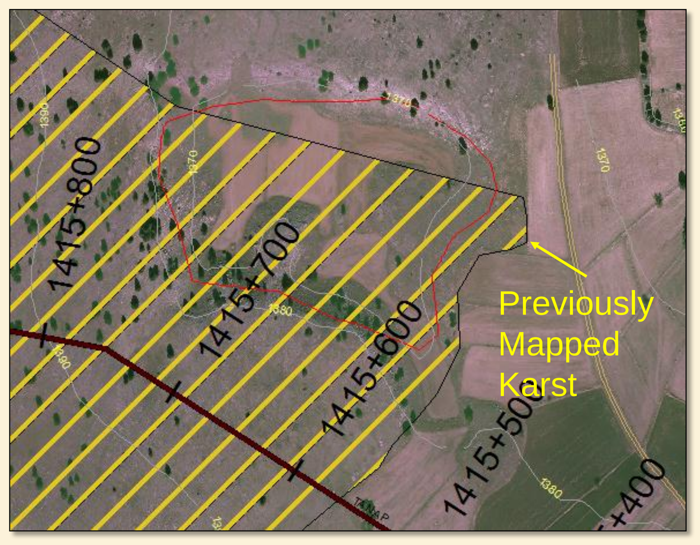
KARST

CLASSIFICATION: Zones of gypsum and carbonate karst were identified, and classified based on a modified version of the Waltham (2002) classification.

HAZARD ASSESSMENT: Extent of karstic gypsum (85 km) and limestone (43 km, plus small areas <0.5 km) were determined based on evidence of subsidence sinkholes/dolines, solution sinkholes/dolines, and collapse sinkholes/dolines. Hazard in limestone was considered negligible for pipeline rupture. Gypsum was further classified based on karstic type: margins (2 km), polygonal (10 km), plateau (20 km), immature (10 km), mantled (21 km), and polje (32 km). Hazard for pipeline rupture was considered highest for plateau karst areas.



ENGINEERING RECOMMENDATIONS: Locally re-route pipeline to follow bedrock exposures and minimize crossing identified sinkholes. Implement surface drainage controls to minimize sinkhole evolution. Minimize pipeline length along karst margins. Install thicker pipe capable of 30-m free spans in area of plateau karst area (20 km).



RIVER CROSSINGS

CLASSIFICATION: Crossings initially were categorized based on width, from large rivers (>30 m) to small streams (<3 m). Information regarding the bed material, cross section, geometry, and setting of river crossings were collected.

HAZARD ASSESSMENT: Fluvial processes that could cause pipeline rupture include river bed scour, bank erosion, and avulsion (channel switching). Hazard assessments were included for all rivers >10 m width and some large streams (3 to 10 m width), to evaluate local and long-term scour depths, active river widths, and 100-yr flood water depths. The assessment considered river channel topography, bed material, river stability, bank scour, cut lines, silt deposits, obstructions, trash lines, and vegetative cover.

ENGINEERING RECOMMENDATIONS: Include concrete coating and/or install helical screw anchors to provide buoyancy control based on flood depths. Within active channel zone (depth and width), consider horizontal directional drilling or jacking and boring, if open-cut construction will not provide adequate burial depth and length.

LANDSLIDES

CLASSIFICATION: Numerous landslides were encountered along the alignment. These landslides were characterized based on the Varnes (1978) classification, and the size and position relative to the alignment were measured.

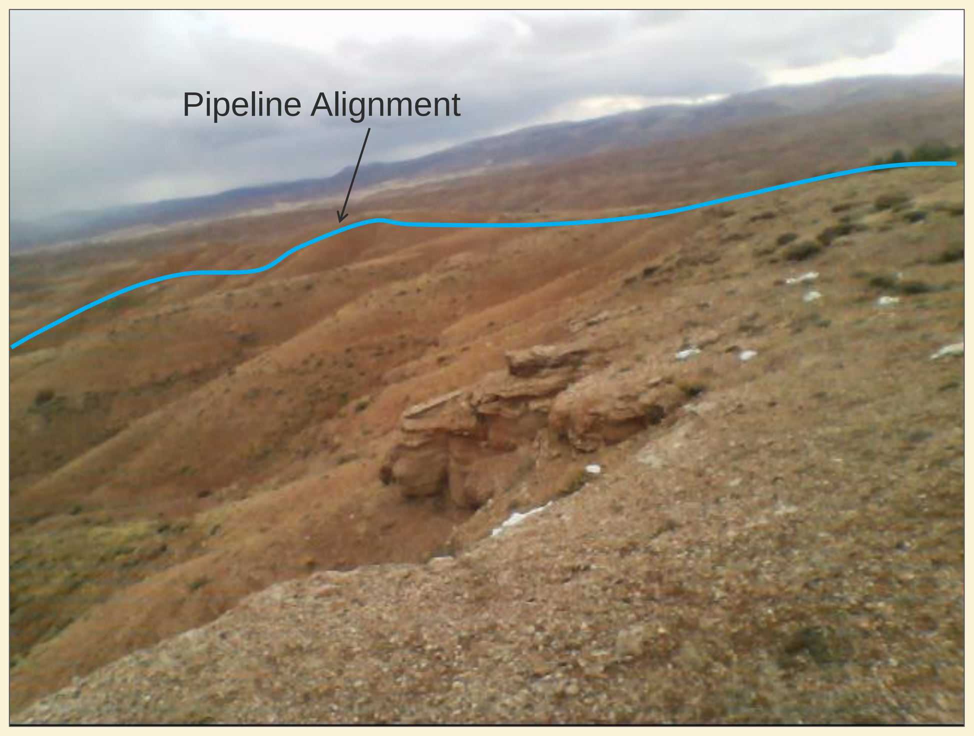
HAZARD ASSESSMENT: Potential for pipeline rupture was qualitatively assessed, considering potential for head scarp regression, run-out, and lateral expansion of active slides, and possible reactivation of inactive slides. Depth classes of shallow (<1 m), intermediate, and deep (>6 m), and distance from pipeline, were estimated. Twenty of 309 landslides were estimated to be medium to high hazard.

ENGINEERING RECOMMENDATIONS: Re-route pipeline to avoid 16 of 20 landslides within the right-of-way with medium to high potential for pipeline rupture. Deep burial beneath four shallow slides considered but requires site investigations to confirm constructability. Attention to surface drainage required near landslides.

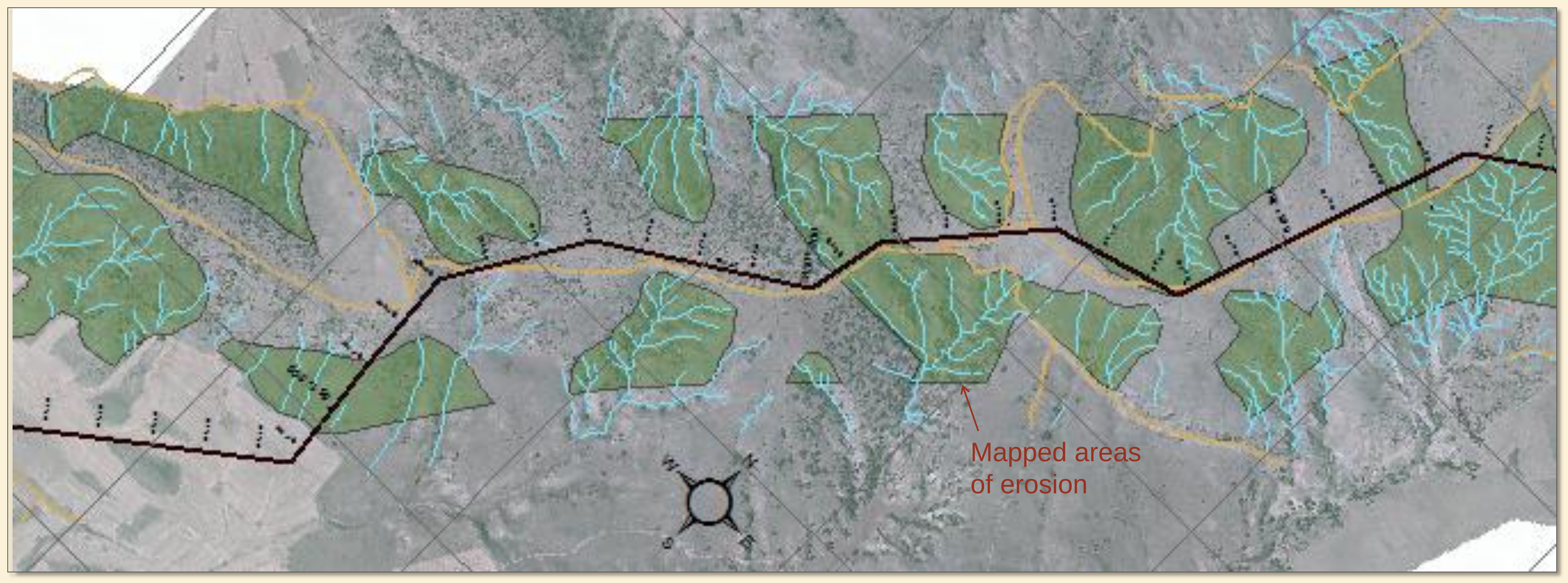
DISSECTED TERRAIN

CLASSIFICATION: Dissected terrain was classified as active or latent areas of erosion.

HAZARD ASSESSMENT: Gullied terrains (15 km) were grouped into categories based on intensity of badland processes, indicated by gully network density, ridge narrowness, slope steepness, vegetative cover, and material weathering. A qualitative hazard assessment considered pipeline location (ridge crest or side slope), proximity, and badlands process (surface erosion, gully deepening/widening, gully head retreat, and shallow slides).

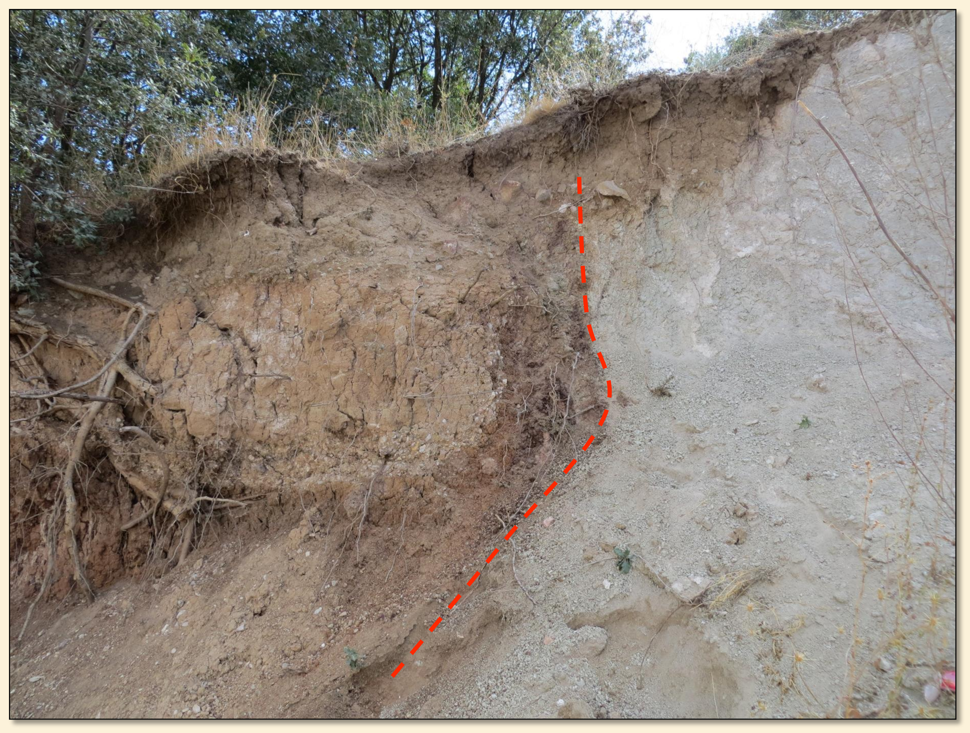


ENGINEERING RECOMMENDATIONS. Pipeline typically is routed along ridge crests in such terrain, so negligible likelihood of pipeline rupture from continuing erosion. However, route inspection is required during operation to identify and remediate erosion/gullying before creating unsupported pipeline spans.



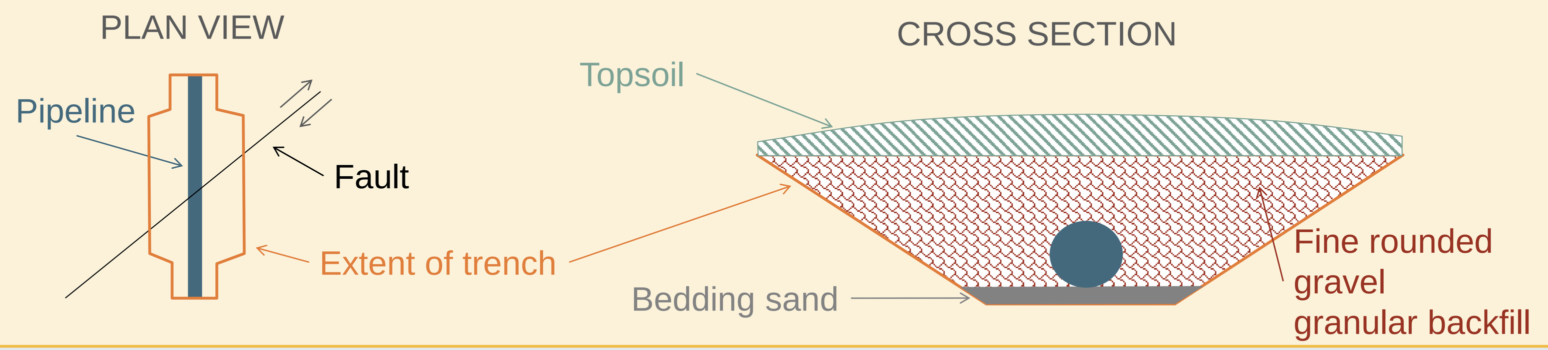
ACTIVE FAULTS

CLASSIFICATION: Crossings of active faults were classified as Category A with historical rupture, large magnitude, and surface displacements of more than a couple meters (at four locations), Category B with Holocene activity, moderate to large earthquakes, with displacements of 0.5 to couple meters, and Category C with Holocene or late Quaternary activity, and displacements <0.5 m.



HAZARD ASSESSMENT: Identified 12 locations crossing faults with large historical displacement (Category A), six locations crossing Holocene faults with displacements of 0.5 to couple meters (Category B), and two locations crossing Holocene/late Quaternary faults with displacements <0.5 m.

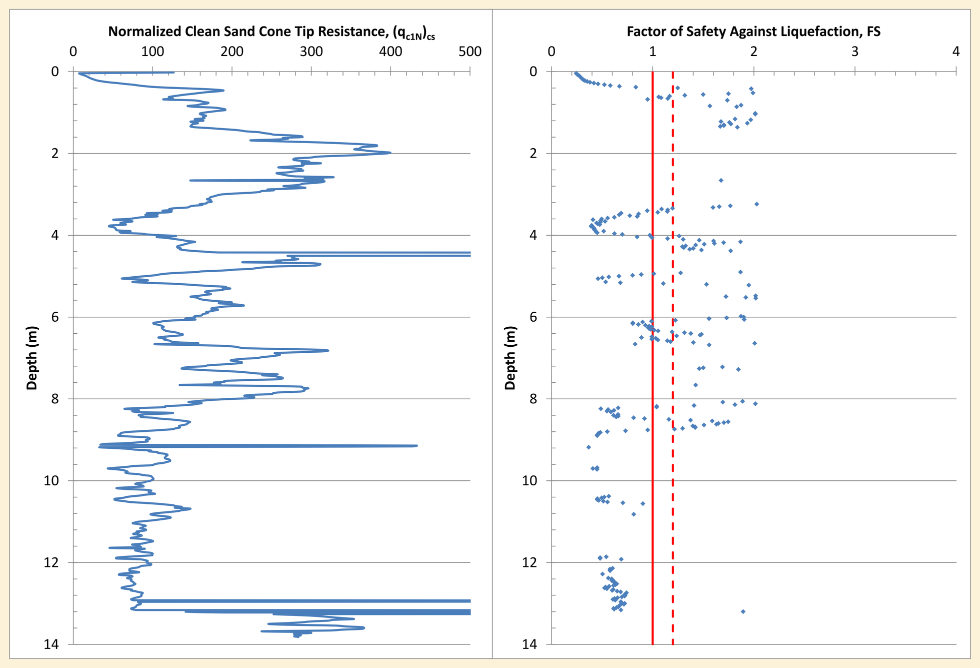
ENGINEERING RECOMMENDATIONS: Install trapezoidal trenches with loose granular fill at 12 fault crossings to allow pipeline to deform without rupturing. Approach angle and trench dimensions to be determined from finite element model analyses that will consider fault-specific movement vectors (direction and magnitude).



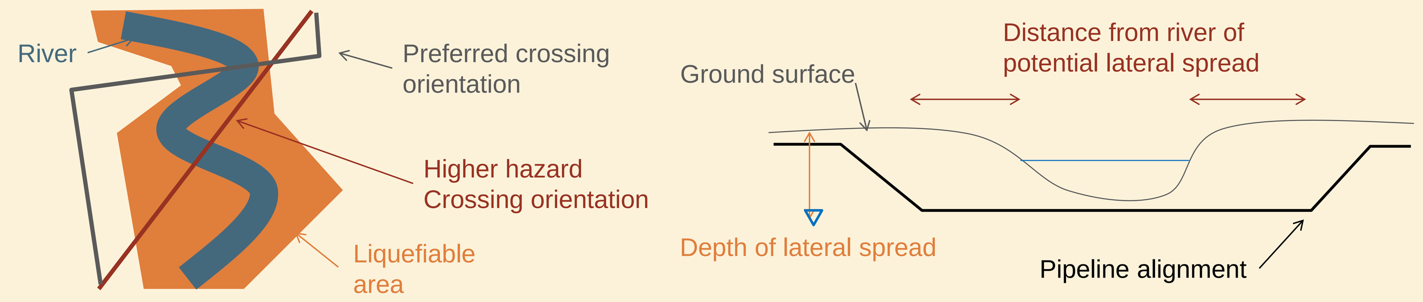
LIQUEFACTION

CLASSIFICATION: Locations with observed or suspected saturated, granular material were classified as potential liquefiable areas.

HAZARD ASSESSMENT: CPTs and boreholes were performed in the potentially liquefiable areas and liquefaction triggering calculations performed to evaluate the factor of safety against liquefaction.



ENGINEERING RECOMMENDATIONS: Install pipeline tie-downs/anchors in zones susceptible to liquefaction to resist uplift. Locally re-route to eliminate lengths adjacent and parallel to a free face (e.g., river bank). Include deeper burial below zones of potential lateral spreading.



FINAL DESGIN

FIELD INVESTIGATIONS: A LiDAR survey should supplement previous field investigation of landslides, active faults, and deep gullies. A fault trenching and paleoseismic program to identify location of faults at pipeline crossing and to determine magnitude, direction, and timing of fault movement. Additional drilling, CPTs, and trial pits to fill in data gaps for landslides, faults, river crossing, and karst ground. Additional cross-section surveys and sediment sample collection/analysis for river crossings where site-specific evaluations are required.

FIELD RECONNAISSANCE: Geohazard reconnaissance to identify gaps resulting from pipeline re-routes and relocation of supporting equipment.

GEOHAZARD ANALYSES: Probabilistic Seismic Hazard Analysis to provide PGA and Mw along final route (for station locations and also potential liquefaction and landslide areas). Interpretation of LiDAR survey for identification of landslides, active faults, and deep gullies. Active fault and splay crossing analysis of displacement magnitude and direction. Evaluation of engineering solutions (stabilization measures) for locations where residual risk for landslides exists after rerouting. Hazard assessment for seismic triggering of landslides. Lateral spreading analyses near open faces.

REFERENCES

Varnes, D. J. (1978). Slope movement types and processes. Transportation Research Board Special Report, (176).
Waltham, T., (2002). The engineering classification of karst with respect to the role and influence of caves. Int. J. Speleology. 31 (1/4), 19–35.

ACKNOWLEDGMENTS

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